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# Properties of Sugary-2 Maize Starch: Influence of Exotic Background.

## Abstract

Genetic modifiers of maize (*Zea mays* L.) starch thermal properties were examined by differential scanning calorimetry (DSC). Sugary- 2 (su2) kernels from segregating ears were identified based on textural appearance of starches following crosses between an exotic maize accession with the inbred OH43 homozygous for the su2 allele (OH43 su2). Two exotic maize accessions, PI213768 and PI451692, were used. Germs retained from su2 kernels were used to produce an F2 population of su2 plants containing 50% exotic germ plasm. With few exceptions, F2 ears from the populations were homozygous for the su2 allele. Significant ( $P$  less than or equal to 0.05) differences were seen between the exotic populations and OH43 su2 for gelatinization onset temperature ( $T_o$ ), range (RN), enthalpy ( $\Delta H$ ), and retrogradation (%R). The number of DSC values with significant within-population variations was greater among F2 ears within the exotic populations than among ears within the inbred line OH43 su2. Standard deviations for DSC values were consistently greater for exotic su2 populations than for those of OH43 su2. Also, the population PI213768 su2 differed greatly from OH43 su2 for mean values of  $T_o$ , RN,  $\Delta H$ , and %R (52.8 C, 13.4 C, 1.5 cal/g, and 34.5%, respectively) when compared to those of OH43 su2 (54.6 C, 10.6 C, 1.3 cal/g, and 29%, respectively). Results from this study indicate that examining the texture of starches from single kernels may be used to identify and develop populations homozygous for the su2 allele. In addition, the increased variability for DSC values within populations containing 50% exotic germ plasm suggest that genetic modifiers might be used to alter thermal properties and, possibly, functional properties of su2 starch.

## Disciplines

Food Biotechnology | Food Processing | Food Science | Human and Clinical Nutrition

## Comments

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# Properties of Sugary-2 Maize Starch: Influence of Exotic Background<sup>1</sup>

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## ABSTRACT

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Genetic modifiers of maize (*Zea mays* L.) starch thermal properties were examined by differential scanning calorimetry (DSC). Sugary-2 (*su*<sub>2</sub>) kernels from segregating ears were identified based on textural appearance of starches following crosses between an exotic maize accession with the inbred OH43 homozygous for the *su*<sub>2</sub> allele (OH43*su*<sub>2</sub>). Two exotic maize accessions, PI213768 and PI451692, were used. Germs retained from *su*<sub>2</sub> kernels were used to produce an F2 population of *su*<sub>2</sub> plants containing 50% exotic germ plasm. With few exceptions, F2 ears from the populations were homozygous for the *su*<sub>2</sub> allele. Significant ( $P \leq 0.05$ ) differences were seen between the exotic populations and OH43*su*<sub>2</sub> for gelatinization onset temperature ( $T_o$ ), range (RN), enthalpy ( $\Delta H$ ), and retrogradation (%R). The number of DSC values with significant within-population variations was greater among F2 ears within the exotic populations than

among ears within the inbred line OH43*su*<sub>2</sub>. Standard deviations for DSC values were consistently greater for exotic *su*<sub>2</sub> populations than for those of OH43*su*<sub>2</sub>. Also, the population PI213768*su*<sub>2</sub> differed greatly from OH43*su*<sub>2</sub> for mean values of  $T_o$ , RN,  $\Delta H$ , and %R (52.8°C, 13.4°C, 1.5 cal/g, and 34.5%, respectively) when compared to those of OH43*su*<sub>2</sub> (54.6°C, 10.6°C, 1.3 cal/g, and 29%, respectively). Results from this study indicate that examining the texture of starches from single kernels could be used to identify and develop populations homozygous for the *su*<sub>2</sub> allele. In addition, the increased variability for DSC values within populations containing 50% exotic germ plasm suggest that genetic modifiers might be used to alter thermal properties and, possibly, functional properties of *su*<sub>2</sub> starch.

The sugary-2 (*su*<sub>2</sub>) allele in maize (*Zea mays* L.), identified by Eyster in 1934, results in starches with a higher amylose content and a lower birefringence end-point temperature than that of normal corn starch. Differential scanning calorimetry (DSC) thermograms of *su*<sub>2</sub> starch have a lower gelatinization onset temperature ( $T_o$ ), gelatinization peak ( $T_p$ ), and total enthalpy ( $\Delta H$ ) than does normal starch (Inouchi et al 1991a). The *su*<sub>2</sub> starches also have less retrogradation during storage than do normal starches, as measured by DSC (Inouchi et al 1991b, White et al 1994, Campbell et al 1994). In addition, several patents have resulted on the use of starches from genotypes possessing the *su*<sub>2</sub> allele, alone or in combination with other mutant genes, because they display unique physical properties (Katz 1991, White et al 1994).

Modifying genes, having quantitative effects, have been shown to interact with the mutant amylose-extender (*ae*) allele, resulting in a wide range of amylose contents (AM). The effects of modifying genes vary depending on the genetic background. For example, AM of segregating F2 kernels from F1 ears derived from 135 dent inbreds crossed to an *ae* genotype ranged from 36.5 to 64.9% (Bear et al 1958). Similarly, starch characteristics of *su*<sub>2</sub> genotypes vary depending on genetic background. Bear et al (1958) reported a range in AM of 31–42% among ears within a *su*<sub>2</sub> converted inbred line.

The conversion of maize germ plasm using endosperm mutant genes usually involves an initial cross followed by several generations of backcrossing; the segregating mutant kernels are selected visually (Bear et al 1958). Garwood and Creech (1972) provided a description of kernel phenotypes resulting from single- and multiple-endosperm mutations that can be used to discriminate segregating kernels. But Vineyard et al (1958) reported difficulties in identifying segregating *ae* kernels resulting from crosses with

normal maize inbred lines when endosperm color genes are present. In addition, Bear et al (1958) identified differences in kernel color, degree of translucence, and fullness among maize inbreds possessing the *ae* allele. To overcome difficulties in identifying mutant kernels, Haunold and Lindsey (1964) used a chemical analysis that preserved the embryo in a viable state after crosses with a yellow *ae* stock and Missouri Cassel, a nonmutant white variety. Amylose contents were determined from endosperms of F2 kernels to identify those homozygous for the *ae* allele. The germ was removed to preserve the genetic material of *ae* kernels for inclusion in further breeding studies.

Tracy (1990) emphasized the importance of exploring exotic germ plasm for improving quality traits in maize because “much of the maize grown outside the U.S. is consumed directly by humans and has undergone centuries of selection for flavors, aromas, and textures”. Recently, DSC has revealed variations in starch thermal properties among exotic sources of maize germ plasm (White et al 1990, Li et al 1994).

The objectives of this study were to first explore methods for rapidly discriminating *su*<sub>2</sub> kernels from segregating ears while maintaining the viability of the germ. This method was then used to study the possible contribution that genetic factors from two exotic sources of maize germ plasm, differing in kernel texture and color, make in modifying the expression of *su*<sub>2</sub>.

## MATERIALS AND METHODS

### Plant Material

Populations of F2 plants homozygous for the *su*<sub>2</sub> allele containing 50% exotic germ plasm were developed (Fig. 1). In 1992, the accessions PI213768 and PI451692 were used as females in crosses with the inbred OH43*su*<sub>2</sub> in a breeding nursery near Ames, IA. PI213768 is a Great Plains flour-corn landrace with blue kernels collected in Iowa. PI451692 (Cargill north temperate zone Coroico) is an unimproved population composed of 94% tropical germ plasm with floury to flinty-floury kernels and colors ranging from white to varying shades of yellow to occasional red. These maize accessions were obtained from the North Central Regional Plant Introduction Station located in Ames, IA. Three ears per population were harvested and dried to a moisture content of ~13%.

During the winter of 1992–93, F1 plants from seed of the exotic × OH43*su*<sub>2</sub> crosses were grown in the greenhouse (two plants/ear). Plants were self-pollinated and F1 ears (producing F2 kernels segregating for *su*<sub>2</sub>) were harvested at physiological maturity.

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## Identification of *su*<sub>2</sub> Kernels

In the laboratory, using a modified procedure described by Haunold and Lindsey (1964), an approximately equal proportion of F<sub>2</sub> kernels were taken from each ear to screen for homozygous *su*<sub>2</sub> kernels. F<sub>2</sub> kernels were steeped overnight in distilled water and stored at 4°C. After steeping, F<sub>2</sub> germs were carefully removed with a razor blade, allowed to dry at room temperature, and stored in aluminum foil. The F<sub>2</sub> endosperms were steeped for an additional 48 hr in 0.45% sodium metabisulfite at 50°C and starch was extracted as described by White et al (1990).

Preliminary observations were made on starches from several normal and *su*<sub>2</sub> inbred lines, including OH43, after drying at ambient room conditions following the starch isolation procedure. The *su*<sub>2</sub> starches formed hard aggregates upon crushing with a metal spatula, unlike the more floury texture of normal starch (data not shown). The appearance of the air-dried starches from the segregating F<sub>2</sub> kernels also fell into the same two texture types (aggregated and floury) after crushing the starches. To determine the extent to which starches classified by texture corresponded to chemical composition of the starches, a subsample of starches from 116 segregating kernels were assayed for AM.

## Amylose Determination

The AM of single F<sub>2</sub> kernels was determined colorimetrically by dissolving ~5.0 mg of starch in 10 ml of 90% dimethyl sulfoxide containing  $6 \times 10^{-3} M$  iodine (Knutson 1986). One milliliter of the dissolved sample was diluted to 9 ml with H<sub>2</sub>O, and the absorbance was measured at 600 nm on a spectrophotometer (Hitachi U-2000, Tokyo, Japan). Purified AM was prepared from maize starch as described by Schoch (1942) and used to construct a standard curve.

## Embryo Culture

Of 600 F<sub>2</sub> kernels screened, 130 *su*<sub>2</sub> germs were selected, based on whether their starches had an aggregated rather than floury starch texture. In mid-May of 1993, selected embryos were germinated on a growth medium in agar plates containing a modified Murashige and Skoog medium (1962). The medium was prepared with 175 ml of H<sub>2</sub>O, 25 ml of Murashige and Skoog basal salt macronutrient solution (M0654, Sigma Chemical Co., St. Louis, MO), 25 ml of Murashige and Skoog basal salt micronutrient solution (M0529, Sigma), 2.5 g of sucrose, 1.75 g of agar, and 0.5 g L-Asparagine adjusted to pH 6.8. Germination occurred under continuous light at 27°C. At the same time, kernels of OH43*su*<sub>2</sub> were planted in pots containing soil in the greenhouse. After three to four days, germs were removed from the growth chamber and transferred into pots. When plants reached approximately the third leaf stage, they were transferred to the field. Transplants were arranged in a completely randomized design. The populations of F<sub>2</sub> plants containing 50% of the genetic materials from PI213768 or PI451692 were designated as PI213768*su*<sub>2</sub> and PI451692*su*<sub>2</sub>, respectively. A total of 116 F<sub>2</sub>

transplants (PI213768*su*<sub>2</sub> and PI451692*su*<sub>2</sub>) were included in the field experiment, in addition to 64 OH43*su*<sub>2</sub> transplants. Self-pollinations were made for the OH43*su*<sub>2</sub> and F<sub>2</sub> plants, with the exception of several protandrous plants for which pollen was used from another individual within the respective population. F<sub>2</sub> ears (producing F<sub>3</sub> kernels) were harvested and dried as described previously.

From each *su*<sub>2</sub> F<sub>2</sub> population (PI213768*su*<sub>2</sub> and PI451692*su*<sub>2</sub>), and for OH43*su*<sub>2</sub>, 14 ears of the best overall quality were selected for DSC.

## DSC

DSC analysis was done on an analyzer equipped with a thermal-analysis data station (DSC7, Perkin-Elmer Corp., Norwalk, CT). Analysis of starch gelatinization was conducted as described by White et al (1990). Approximately 4.0 mg (dwb) of starch was weighed into aluminum sample pans, then 8 mg of distilled water was added. Samples were heated from 30 to 102°C at a rate of 10°C/min. DSC parameters recorded for this study included  $\Delta H$ ,  $T_o$ ,  $T_p$ , and RN. The parameters  $T_o$ ,  $T_p$ , and  $\Delta H$  were given directly by the DSC software. Because the endotherms were symmetrical, the RN was calculated as  $2(T_p - T_o)$  according to Krueger et al (1987). Samples were stored for seven days at 4°C and rerun using DSC to determine starch gel retrogradation (%R) as described by White et al (1989). A single DSC run was made per kernel from three kernels per ear.

## Statistical Analysis

*F*-tests were used to determine significant effects among and within genotypes from the ANOVA by using a completely randomized design. Pearson's simple correlations were used to identify correlations between DSC values of F<sub>2</sub> kernels produced in the greenhouse and the mean of F<sub>2</sub> ears (F<sub>3</sub> kernels) grown in 1993 (SAS 1990).

## RESULTS AND DISCUSSION

### Identification of Mutant Kernels

Samples of F<sub>1</sub> ears produced in the greenhouse during 1992–93 are shown in Figure 2. As expected, ears segregated for various

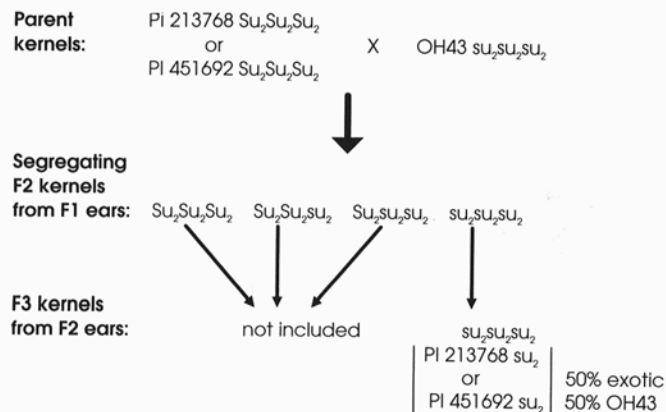


Fig. 1. Scheme for developing *su*<sub>2</sub> maize F<sub>2</sub> populations (PI213768*su*<sub>2</sub> and PI451692*su*<sub>2</sub>) from the cross between the maize accessions PI213768 and PI451692 with OH43*su*<sub>2</sub>.

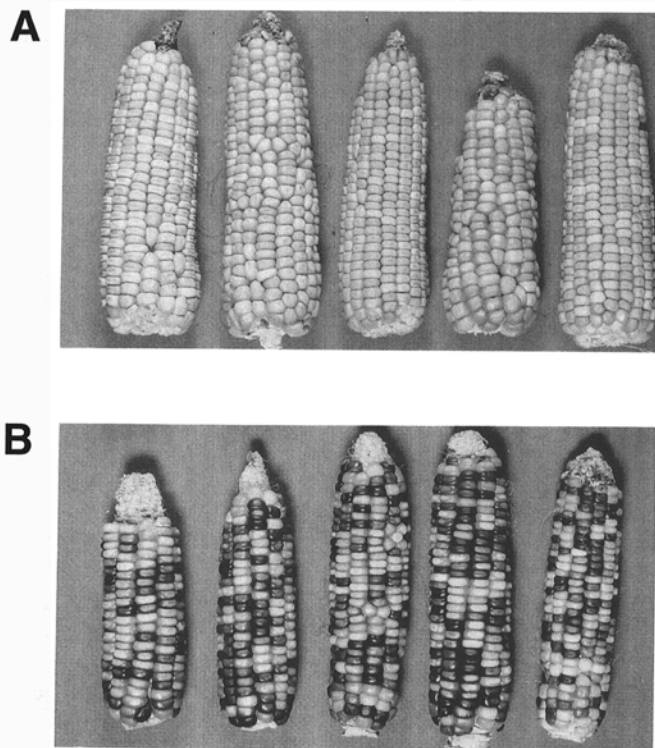


Fig. 2. F<sub>1</sub> ears segregating for *su*<sub>2</sub> maize kernels resulting from crosses between the exotic populations PI451692 (A) and PI213768 (B) with OH43*su*<sub>2</sub>.

kernel colors and textures, in addition to the *su*<sub>2</sub> allele. Phenotypic descriptions of endosperm mutants in Corn Belt dent backgrounds (W64A and W23) provided by Garwood and Creech (1972), indicated a slight tarnished and etched appearance of *su*<sub>2</sub> kernels. Although this description can be used to distinguish *su*<sub>2</sub> from normal kernels in Corn Belt dent germ plasm, in this study, variations in kernel color and texture did not allow easy recognition of these characteristics.

The *su*<sub>2</sub> kernels were selected for textural appearance; starches were either aggregated (*su*<sub>2</sub>) or floury (normal). Percentages of AM were compared with samples of a subsample of 116 kernels classified by starch texture (Table I). Mean AM% of starches classified as aggregated was ~10% greater than mean AM% of normal floury starches for both populations. These means are in agreement with previous reports of a 10–15% increase in AM of starches from *su*<sub>2</sub> genotypes (Shannon and Garwood 1984). Ranges in AM% overlapped between the two starch texture groups among F2 kernels from PI451692 × OH43*su*<sub>2</sub> F1 ears. This may be the result of either inaccuracies in starch texture classification or AM determination. However, genetic variations in these starch traits within *su*<sub>2</sub> mutant and normal kernels could possibly account for the overlapping values. For example, Bear et al (1958) observed ranges in AM% in single kernels of 31–42% among genotypes homozygous for *su*<sub>2</sub>. Use of AM% would be expected to be less reliable in discriminating between *su*<sub>2</sub> and normal genotypes than for discriminating between *ae* and normal genotypes, in which the minimum value of the range (36.5–64.9%) was greater (Bear et al 1958).

#### DSC Values Among F3 Kernels

Initially, 16 F2 ears were selected per population. One of the F2 ears from PI213768*su*<sub>2</sub> and two from PI451692*su*<sub>2</sub> had at least one F3 kernel that gave rise to DSC thermograms resembling normal or dosage-intermediate starches as described by Campbell et al (1994). The presence of normal and dosage-intermediate starches from F3 kernels on an F2 ear strongly indicated that either the ears were segregating for the *su*<sub>2</sub> allele as a result of the F2 plants not being in a homozygous condition, or that contamination by foreign pollen may have occurred. These ears were subsequently eliminated from the study. Therefore, 14 ears were selected from each population to be included for DSC analysis.

DSC values for starches from all individual F3 kernels (data not shown) resembled values reported for *su*<sub>2</sub> genotypes by Inouchi et al (1991a). DSC thermograms also were examined from the originating F2 kernel starches, all of which displayed *su*<sub>2</sub>-type DSC values rather than those typical of normal starch (data not shown). These data support the idea that classification on the basis of starch texture could be used to discriminate *su*<sub>2</sub> kernels segregating on F1 ears, thus providing a means of identifying mutant *su*<sub>2</sub> kernels when color and kernel type interfere with the *su*<sub>2</sub> phenotype. Application of other nondestructive techniques also may be useful in discriminating genotypes homozygous for the mutant *su*<sub>2</sub> allele. Zaitlin (1993), for example, reported use of a molecular marker assay for the waxy allele, based on polymerase chain reaction (PCR), in the conversion of maize lines. This method allows for the unequivocal identification of plants that are homozygous for the recessive allele.

TABLE I

Starches from F2 Kernels Resulting from the Crosses Between PI213768 and PI451692 with OH43*su*<sub>2</sub> Selected for Either Aggregated or Floury Starch Textures and Their Amylose Contents

F1 Population Cross	Starch Texture Type	Number of F2 Kernels	Mean Amylose Content, %	Amylose Range, %
PI213768 × OH43 <i>su</i> <sub>2</sub>	Aggregated	8	35.8	31.7–41.9
	Floury	50	25.0	22.1–31.7
PI451692 × OH43 <i>su</i> <sub>2</sub>	Aggregated	16	34.6	28.1–41.6
	Floury	42	24.4	19.1–30.9

#### Variations Among and Within Populations

Significant differences ( $P \leq 0.05$ ) were observed among the *su*<sub>2</sub> populations of PI213768*su*<sub>2</sub>, PI451692*su*<sub>2</sub> and the inbred OH43*su*<sub>2</sub> for  $T_o$ , RN,  $\Delta H$ , and %R as determined from ANOVA (Table II). Both populations significantly differed from OH43*su*<sub>2</sub> for  $T_o$ , RN, and %R. However, only PI213768*su*<sub>2</sub> differed from OH43*su*<sub>2</sub> for  $\Delta H$ . The two populations differed from each other only for RN and  $\Delta H$ .

Highly significant ( $P \leq 0.01$ ) variations were observed among ears within genotypes for all DSC values with the exception of %R (Table II). When genotypes were examined individually as a source of variation in the ANOVA table, significant variations for DSC values (except %R) occurred among ears within the exotic *su*<sub>2</sub> populations (PI213768*su*<sub>2</sub> and PI451692*su*<sub>2</sub>). But for variations within OH43*su*<sub>2</sub> ears, the level of significance was reduced for  $T_o$  and there were no significant differences for RN and  $\Delta H$ .

Means, ranges, and standard deviations among 14 ears per genotype are compared in Table III. Generally, *su*<sub>2</sub> F2 ears of the exotic populations had lower  $T_o$  and greater RN,  $\Delta H$ , and %R than did OH43*su*<sub>2</sub>. Ranges and standard deviations of DSC values among *su*<sub>2</sub> F2 ears for both exotic populations were greater than were those of OH43*su*<sub>2</sub>. These data indicate that the genetically variable nature of the F2 populations from the exotic materials resulted in greater variations for DSC values.

The influence of exotic germ plasm on DSC parameters suggests that modifying genetic factors may play a role in altering expression of the *su*<sub>2</sub> allele with respect to starch thermal properties. A more thorough screening of exotic sources of maize germ plasm may reveal additional sources of major and minor modifying genes. Several studies have indicated that qualitative and quantitative differences in DSC values reflect variations in starch functional properties (Wang et al 1992, Campbell 1994). Ferguson (1994) demonstrated that selection within populations homozygous for the *ae* allele could be used to effectively increase AM%. Selection based on DSC values within genetically variable *su*<sub>2</sub> populations may also lead to the development of genotypes with desired starch properties.

#### Correlation Analysis

To determine whether DSC values of the starch of F2 kernels could be used to predict thermal properties of the F3 kernels on F2 ears, a correlation analysis was conducted between the two sets of data (Table IV). Correlation coefficients were not high for any DSC value. However, the greatest correlation noted for the RN ( $r = 0.37$ ) did approach significance ( $P = 0.056$ ). In a similar study by Haunold and Lindsey (1964), a significant

TABLE II  
Levels of Significance for the Effects of Genotype and Ears Within Genotype for *su*<sub>2</sub> F2 Ears from Exotic × OH43*su*<sub>2</sub> Crosses and OH43*su*<sub>2</sub>

Source	DF	$T_o^a$	$T_p^b$	RN <sup>c</sup>	$\Delta H^d$	%R <sup>e</sup>
Genotype	2	**	NS <sup>f</sup>	**	*	*
PI213768 <i>su</i> <sub>2</sub> vs OH43 <i>su</i> <sub>2</sub>	1	**	NS	**	**	**
PI451692 <i>su</i> <sub>2</sub> vs OH43 <i>su</i> <sub>2</sub>	1	*	NS	**	NS	*
PI213768 <i>su</i> <sub>2</sub> vs PI451692 <i>su</i> <sub>2</sub>	1	NS	NS	**	**	NS
Ears (Genotype)	39	**	**	**	**	NS
Ears (PI213768 <i>su</i> <sub>2</sub> )	13	**	**	**	**	NS
Ears (PI451692 <i>su</i> <sub>2</sub> )	13	**	**	**	**	NS
Ears (OH43 <i>su</i> <sub>2</sub> )	13	*	**	NS	NS	NS
Error	84	...	...	...	...	...
CV% <sup>h</sup>		2.0	1.6	12.4	11.3	22.4

<sup>a</sup> Gelatinization onset temperature.

<sup>b</sup> Gelatinization peak temperature.

<sup>c</sup> Gelatinization range.

<sup>d</sup> Enthalpy of gelatinization.

<sup>e</sup> Retrogradation ( $\Delta H$  initial run/ $\Delta H$  rerun after seven days at 4.0°C) × 100.

<sup>f</sup> \*, \*\* = Significant at  $P \leq 0.05$  and 0.01, respectively.

<sup>g</sup> Not significant at  $P \leq 0.05$ .

<sup>h</sup> Coefficient of variation.

**TABLE III**  
Means, Standard Deviations (SD), and Ranges for Differential Scanning Calorimetry Values  
Determined from *su*<sub>2</sub> F2 Ears (PI213768*su*<sub>2</sub> and PI451692*su*<sub>2</sub>) and OH43*su*<sub>2</sub>

<i>su</i> <sub>2</sub> F2 Population (Exotic × OH43 <i>su</i> <sub>2</sub> )	Number of Ears	Mean ± SD (Range)				
		<i>T</i> <sub>o</sub> <sup>a</sup>	<i>T</i> <sub>p</sub> <sup>b</sup>	RN <sup>c</sup>	Δ <i>H</i> <sup>d</sup>	% <i>R</i> <sup>e</sup>
PI213768 <i>su</i> <sub>2</sub>	14	52.8 ± 1.6 (50.4–55.7)	59.5 ± 1.1 (57.7–61.3)	13.4 ± 1.7 (11.3–16.3)	1.5 ± 0.16 (1.2–1.7)	34.5 ± 4.8 (26.7–47.0)
PI451692 <i>su</i> <sub>2</sub>	14	53.5 ± 1.3 (50.8–55.9)	59.6 ± 1.0 (57.9–61.8)	12.2 ± 1.3 (9.0–14.3)	1.3 ± 0.21 (1.0–1.6)	32.9 ± 5.1 (26.1–42.2)
OH43 <i>su</i> <sub>2</sub>	14	54.6 ± 0.8 (53.7–56.2)	59.9 ± 0.8 (59.1–61.6)	10.6 ± 0.7 (9.5–11.9)	1.3 ± 0.05 (1.2–1.4)	29.0 ± 4.1 (21.1–35.3)

<sup>a</sup>Gelatinization onset temperature (°C).

<sup>b</sup>Gelatinization peak temperature (°C).

<sup>c</sup>Gelatinization range (°C).

<sup>d</sup>Enthalpy of gelatinization (cal/g).

<sup>e</sup>Retrogradation (%) (Δ*H* initial run/Δ*H* rerun after seven days at 4.0°C) × 100.

**TABLE IV**  
Correlations Between Differential Scanning Calorimetry Values  
Determined from *su*<sub>2</sub> F2 Kernels Harvested During 1992–93 and the  
Mean of F3 *su*<sub>2</sub> Kernels Obtained from F2 Ears Harvested in 1993

DSC Value	Correlation Coefficient
<i>T</i> <sub>o</sub> <sup>a</sup>	−0.05
<i>T</i> <sub>p</sub> <sup>b</sup>	0.00
Δ <i>H</i> <sup>c</sup>	−0.15
RN <sup>d</sup>	0.37
% <i>R</i> <sup>e</sup>	−0.01

<sup>a</sup>Gelatinization onset temperature (°C).

<sup>b</sup>Gelatinization peak temperature (°C).

<sup>c</sup>Enthalpy of gelatinization (cal/g).

<sup>d</sup>Gelatinization range (°C).

<sup>e</sup>Retrogradation (%) (Δ*H* initial run/Δ*H* rerun after seven days at 4.0°C) × 100.

correlation ( $r = 0.52$ ,  $P \leq 0.01$ ) occurred between F2 kernels and F2 ears for amylose content within a genetically variable *ae* population. The authors suggested that selection based on F1 kernels could be advantageous in selecting desirable high-amylose genotypes in early stages of line development. The lack of significant correlations in this study could be the result of inadequate variability within populations or the extremely different environments in which plants were grown (field vs. greenhouse).

## CONCLUSION

The formation of hard aggregates versus a floury texture after drying starches was used as a basis for identifying kernels homozygous for the *su*<sub>2</sub> allele. This method was effective in creating populations of homozygous *su*<sub>2</sub> F2 ears containing 50% exotic germ plasm from a total of 32 ears (with the exception of three F2 ears) selected as homozygous *su*<sub>2</sub>. Identification of *su*<sub>2</sub> kernels in this manner, therefore, is useful when visual identification of mutant phenotypes is masked because of variations in kernel color and texture. In addition, this study provides evidence that populations containing 50% exotic maize germ plasm possess genetic modifiers, as indicated from the increased variances in DSC values of the starches, compared to the variances observed within the inbred line OH43*su*<sub>2</sub>.

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